On the modes of mantle convection in the early Earth

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The modes of mantle convection through Earth history, i.e., when plate tectonics started on Earth, or what kind of mantle dynamics governed the early Earth, is among the most heatedly debated topics in earth and planetary sciences, as it provides a fundamental control on the physical and chemical evolution of this planet. Naturally, a better understanding of this difficult issue requires multidisciplinary efforts, but before integrating different arguments from different disciplines, it is essential to scrutinize the quality of individual arguments. As it transpired recently [1,2], the debate over the modes of mantle convection has been in a profoundly confused state over the past decade or so, owing to the misinterpretation of geodynamical models as well as relevant geological data. In this talk, therefore, I will first briefly explain the flaws of a few representative studies on the modes of mantle convection. I will then explain how different kinds of continental growth models can constrain the history of plate tectonics. Rapid crustal growth and efficient crustal recycling indicated by the geochemical box modeling of Nd isotope systems [3] are shown to be in full agreement with a new estimate on the formation age distribution of extant continental crust based on detrital zircon [2]. The confluence of these two entirely different geochemical approaches points to the very early onset of plate tectonics, possibly soon after the solidification of a magma ocean, and furthermore, the vigor of such early plate tectonics is likely to have been intense. In the latter half of the talk, I will discuss the latest development in the physics and chemistry of magma ocean solidification [4,5] and its implications for Hadean mantle dynamics. A new generation of magma ocean modeling with internally consistent thermodynamics suggests that subsolidus mantle convection may have started with a chemically heterogeneous mantle, which has intriguing connections to the efficiency of carbon sequestration, the redox evolution of surface environment, and the composition of early crust.

[1] Korenaga (2017) *JGR* **122**, 4064-4085. [2] Korenaga (2018) *EPSL* **482**, 388-395. [3] Rosas & Korenaga (2018) *EPSL* **494**, 42-49. [4] Miyazaki & Korenaga (2019a) *JGR* **124**, doi.org/10.1029/2018JB016932. [5] Miyazaki & Korenaga (2019b) *JGR* **124**, doi.org/10.1029/2018JB016928.